

**BASIC AERODYNAMIC RESEARCH FACILITY
FOR COMPARATIVE STUDIES
OF FLOW DIAGNOSTIC TECHNIQUES**

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PURPOSE OF INVESTIGATION

The development of flow diagnostic techniques has gained renewed momentum in recent years due to the rising need to validate Computational Fluid Dynamics (CFD) results. While CFD has made great strides in the understanding of certain basic flow fields, there are still voids in the understanding of flow physics dealing with boundary-layer transition, turbulence, and separation.

For instance, the requirements of CFD for three component data of mean velocity, turbulence levels, and Reynolds stresses are limited to measurement techniques that can handle both mean and fluctuating flow quantities. While laser velocimetry (LV) systems have an advantage of being nonintrusive and very good at measuring mean velocity in unseparated and separated flow fields, they are weak in measuring low disturbance levels. In contrast, hot wire techniques are considered good in low turbulence flow fields, yet poor at measuring mean flow quantities. These strengths and weaknesses are expected to be compounded in the transonic flow regime where compressibility influences the outcome of each measurement. The flow regimes where the different instruments have general agreement is also expected to change with increased Mach number. These areas of mutual agreement will therefore be an area of interest in this test series. Thus, it is the basic purpose of this investigation to compare 3-D measurements obtained with a hot wire system to those obtained with an orthogonal LV system (fig. 1).

Current flow diagnostic research efforts are focusing on the higher order flow field data bases, such as those generated by laser velocimetry, hot wire anemometry, and multi-hole pressure probes. These instruments are being used in studies that range from simple 2-D flow fields, such as a flat plate boundary layer, to complex 3-D efforts, which include unsteady vortex flows generated by a delta wing.

Recent low-speed comparisons of results obtained with LV and hot wires (refs. 35 and 36) have revealed strengths and weaknesses of each instrument. To extend this comparative process to transonic speeds, the Basic Aerodynamic Research Facility was modified for a customized orthogonal 3-D LV system.

- Comparison of three-component measurements from hot-wire anemometry and orthogonal LV system
- Hot-wire anemometer suitable for low-level fluctuations
- Laser velocimeter suitable for higher levels of fluctuations and is nonintrusive
- Area of mutual agreement of two-methods to be determined

Figure 1

TEST FACILITY AND FLOW CONDITIONS

A test plan (fig. 2) has been derived that will focus on the differences in the two measurement techniques at both sub- and transonic speeds. The first phase is expected to show areas of mutual agreement at low speeds ($Mach < 0.4$). To eliminate mean velocity gradient and surface problems the initial test series will be performed behind a uniform turbulence grid. The classic turbulence decay format will represent turbulence magnitude and length scale variations. The second test series will be performed in a sub- and transonic 2-D shear flow field in the wake of a flat plate. Utilizing the velocity gradient, without a surface, will focus on the control volume size of both the LV and the hot wire. Moving upstream to the turbulent boundary layer of the flat plate will then introduce a surface effect, again concentrating on control volume size and laser flair. The final test series of this comparative study will address a 3-D vortical flow field at transonic speeds ($0.5 < Mach < 1.3$).

- Atmospheric — continuous tunnel
- Subsonic tests at Mach numbers from 0.1 to 0.4 for \tilde{u} , \tilde{v} , \tilde{w} from both LV and hot wire measurements
- Transonic tests at Mach numbers from 0.4 to 1.2 for \tilde{u} , \tilde{v} , \tilde{w} from LV system and \tilde{u} , $\tilde{\rho}$, \tilde{T}_t from hot-wire system
- Top and side walls of test section made of glass

Figure 2

TEST SECTION OF BASIC AERODYNAMIC RESEARCH FACILITY FOR USE WITH ORTHOGONAL LV SYSTEM

The test section of the Basic Aerodynamics Research Facility (fig. 3) was designed for optical access for an orthogonal 3 component LV system (ref. 15). This constraint required the slots to be moved to the corner of the test section. Comparison of the performance of the new LV test section to that of the uniform 6 slot configuration showed minimal deviation in the Mach number distribution through a Mach number range up to 1.3. The primary effect was a degradation of the re-entry flap performance and diffuser efficiency.

As part of the initial test plan, a seeding study will be initiated to determine particulate tracking ability. This will be performed over the entire Mach number range of the tunnel. The stagnation line on a sphere will be used as the test case. Spheres of different sizes will be used as computations of the stagnation flow may be influenced by model blockage.

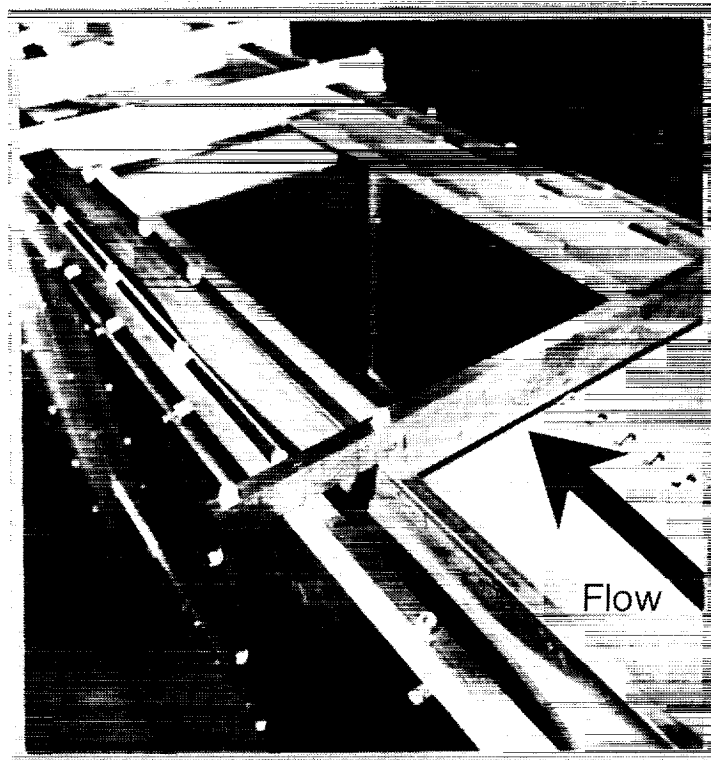


Figure 3

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OPTICS OF THREE-COMPONENT ORTHOGONAL LV SYSTEM

The 3-D orthogonal capability of the LV optics (fig. 4) makes the Basic Aerodynamics Research Facility a one-of-a-kind transonic facility. The flexibility of the paneled test section is enhanced by the flexibility of the LV optical system itself. Not only is the system capable of 3-D orthogonal measurements but also can be arranged in off-axis backscatter or forward scatter off-axis 3-D orientations. This allows the researcher to optimize the optical access to any variety of 2-D or 3-D models. It also gives the researcher the ability to compare different 3-D LV optical schemes directly.

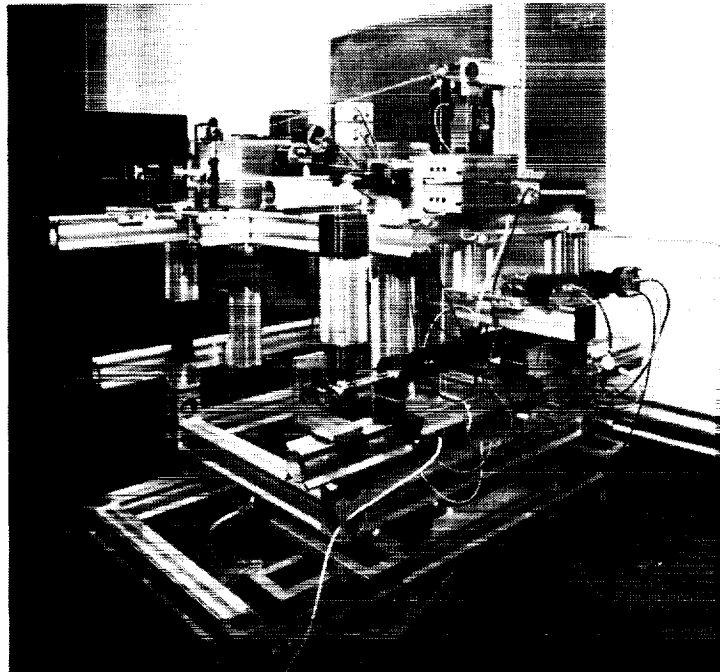


Figure 4

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LV TRAVERSING SYSTEM TO OFFER FLEXIBILITY IN STUDYING
DIFFERENT 3-D OPTICAL CONFIGURATIONS

The LV traversing system is designed to offer flexibility in orienting the transmitting and/or receiving optics to either a forward scatter or backscatter system (fig. 5). This allows the researcher to optimize the optical access to any variety of 2-D or 3-D models. It also gives the researcher the ability to compare different 3-D and LV optical schemes directly.

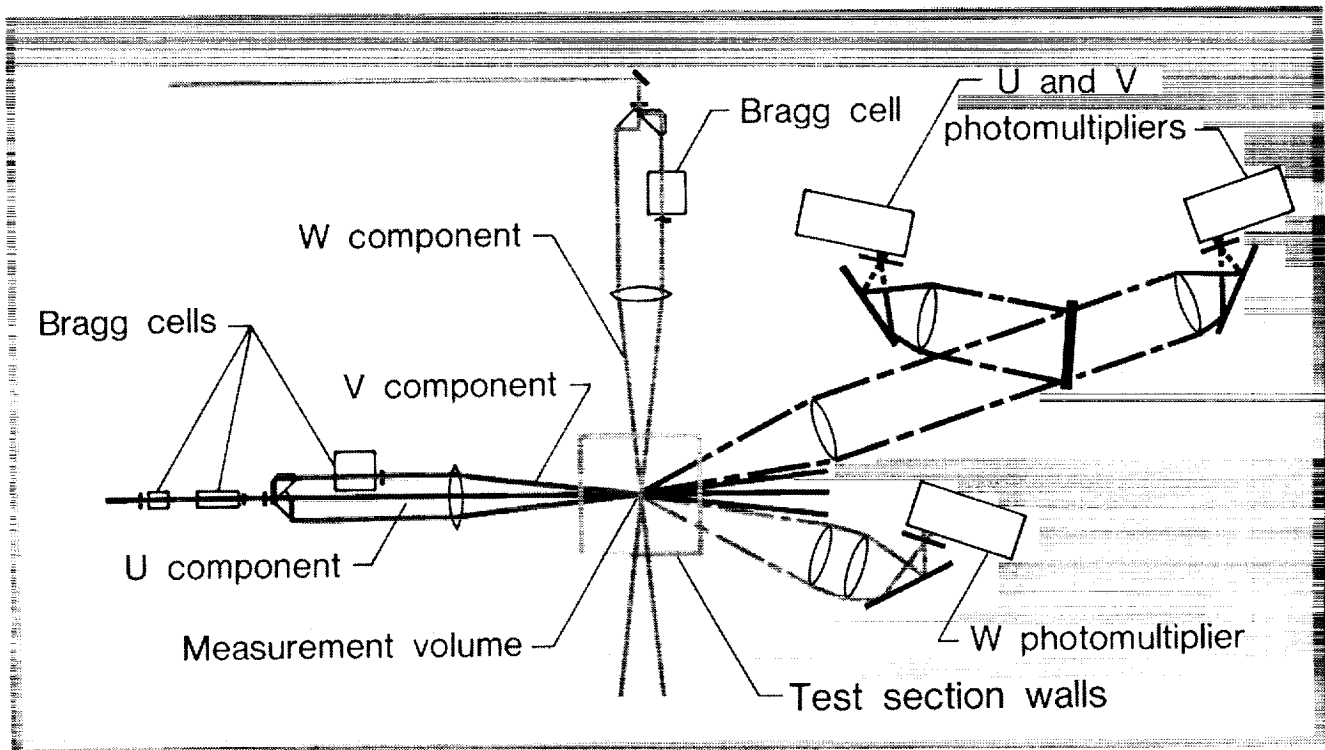


Figure 5

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